Network Percolation Theory

I am working on the problem of redefining the theory of percolation when the definition of connectivity is modified to take into account distance. To illustrate this with an example, consider a communication network, where long paths tend to be less reliable and secure than shorter paths. In the event of a failure of some nodes/links along the path, rerouting of a message becomes necessary. However, if the new message route is much longer than the original route, there is a higher likelihood of loosing the message. By modifying the definition of connectivity to mean that the new path cannot be larger than a certain fraction over the length of the original path, we correctly account for the message passing performance of the network. We have found that, with this definition, a new percolation transition appears, at a smaller threshold failure rate than that predicted by regular percolation. Also, the scaling of the size of the connected network shows several interesting phases: a linear phase for connectivity above the new failure threshold; a power-law phase for a range of values of the failure rate between the new threshold and the classic threshold; and a logarithmic phase below the classic failure threshold. This work is of relevance in the design of networks, as well as problems of epidemics and transportation.

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